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Fluctuation of drift velocity in electrophoresis of charged particles

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電気泳動測定は，荷電粒子（コロイド・タンパク質・DNA など）のキャラクタリゼーションや分離にとって有用な手段であり，古くからその基礎付けとして国内外で理論・数値計算による研究が広くなされてきた．しかしながら，一粒子に限っても粒子・イオン場・流れ場などを考慮しなければならず，未だ分っていない点も多い．さらに，多粒子系においては静的な静電相互作用の他，流体力学的相互作用といった動的な相互作用も考慮しなければならず，その重要性に拘らずほとんど研究されていないといっても過言ではない．我々は，イオンの自由度を取り入れた流体粒子ダイナミクス法を用いて，多粒子系の電気泳動に関する研究を行った．その結果，多体相互作用のため粒子運動が時間的・空間的に揺らぐことを見出し，それが適当な量の塩を添加することで抑制できることを示した．

Electrophoresis is one of the most important methods for separating colloid particles and biological molecules such as DNA and proteins, in terms of their charge. This method relies on the correlation between the particle drift velocity and the charge. For a high-resolution separation, we need to minimize fluctuations of the drift velocity of particles or molecules. For a high throughput, on the other hand, we need a concentrated solution, in which many-body electrostatic and hydrodynamic interactions may increase velocity fluctuations. Thus, it is crucial to reveal what physical factors destablize coherent electrophoretic motion of charged particles. However, this is not an easy task due to complex dynamic coupling among particle motion, hydrodynamic flow, and motion of ion clouds. Here we study this fundamental problem by numerical simulations, fully incorporating these couplings. We reveal that addition of salt screens both electrostatic and hydrodynamic interactions, but in a different manner. This allows us to control the electrophoretic behavior in terms of salinity. We demonstrate that the fluctuations of the particle drift velocity can be minimized for a particular salinity.

References

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